GREAT LAKES WATER RESOURCES FORECASTING

PURPOSE. High and low Great Lakes levels cause extensive flooding, erosion, and damage to shorelines, shipping, and hydropower. The ***International Joint Commission***, at the request of the US and Canadian governments, recommended improving forecast methodologies, hydrological models, data collection, and communication of hydrological forecast information.

While forecasts of meteorology, riverine flooding, and water level fluctuations are available for several hours to several days, the Great Lakes community requires ***water resource forecasts*** over large areas and time periods. Products must include ***nowcasts*** and 1-day to 3-month ***probabilistic outlooks*** of lake supplies, lake levels, and connecting channel flows. These require careful tracking of moisture storage variables and heat storage variables. The products must be relevant to users and delivered in a clear and understandable manner that aids in planning and decision making. They must make maximum use of all available information and be based on efficient and true hydrological process models.

OBJECTIVES.

- ***Develop new suite of products.***
  identify users & forecast products
  enhance usability of outlooks
  address spatial variability in outlooks
  expand nowcasts & probabilistic outlooks
- ***Integrate data management & analysis.***
  use NWS modernization
  use new GIS & relational databases
- ***Build process model components.***
  use distributed spatial models
  integrate hydrology & atmosphere
- ***Demonstrate system on Great Lakes.***
- ***Transfer technology.***

BACKGROUND. As far as water resources forecasting in the Great Lakes is concerned, the ***US Lake Survey*** began 6-month lake level forecasts in 1952; the ***Canadian Hydrographic Service*** began estimating levels with probabilistic supply forecasts in 1973; and ***US Army Corps of Engineers*** began estimating levels with statistical supply forecasts in 1975. Now, 8,000 US and 2,600 Canadian bulletins are distributed, coordinated between the two countries. As far as water resources forecasting at GLERL is concerned, GLERL adapted runoff models to estimate supplies in 1982, installed their forecast package for the US Army Corps of Engineers on Lake Superior in 1983, for the NWS Northeast River Forecast Center on Lake Champlain in 1984, for 3 Corps offices on all Great Lakes in 1987, for the New York Power Authority and Ontario Hydro in 1988, and for the Midwest Climate Center in 1994. GLERL identified weak evaporation estimates in 1985, added improved 1-D evaporation models in 1990, altered deterministic outlooks, added probabilistic outlooks, and re-evaluated in 1993 as well as identified meteorological outlooks as the weakest part of the outlook. The Great Lakes Environmental Research Laboratory developed a semiautomatic ***software package*** for making forecasts of basin ***moisture storage***

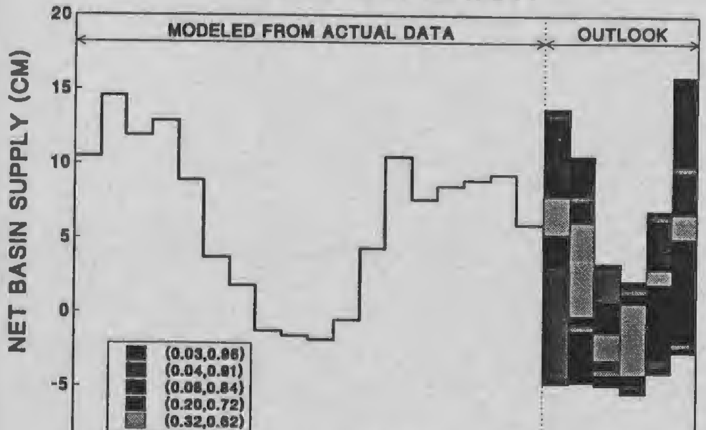
Lake Superior 1-Month Deterministic Outlook Statistics

Method	Skill	RMSE (mm)	Corr.	Bias (mm)	Max. Error (mm)
Corps[a]	0.96	44	0.75	-2	132
Canadian[b]	1.00	44	0.75	3	131
ARMA[c]	0.92	42	0.77	4	132
Group A[d]	0.87	32	0.88	8	116
Group B	0.92	35	0.86	7	122
Group C	0.94	36	0.85	8	124
Group D	0.92	38	0.83	2	115
Group E	0.82	37	0.85	5	95

[a] U.S. Army Corps of Engineers trend and regression.
[b] Environment Canada 5% & 95% forecasts averaged.
[c] Univariate ARMA Model, commissioned by the Corps.
[d] GLERL groups: ***A*** is all historical meteorology sequences; ***B*** matches NWS 30-day temperature (T) outlooks; ***C*** matches 30-D T and precipitation (P) (Winter & Spring forecasts) or 30-D T and 90-D T (Summer & Fall); ***D*** matches 30-D T, 30-D P, and 90-D T; ***E*** matches 30-D T, 30-D P, 90-D T, and 90-D P.

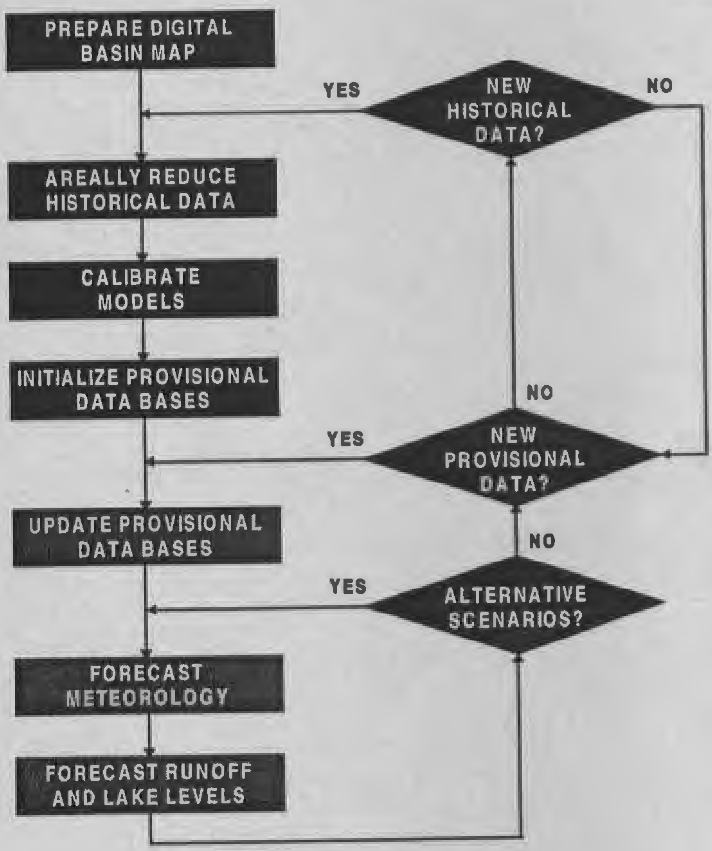
DETERMINISTIC OUTLOOKS. Net basin supply outlooks are better than climatology, and GLERL's physically-based methods perform ***best in every regard*** for first-month outlooks on Lakes Superior, Michigan-Huron, and Erie. Over other lakes, they perform ***better in every regard but one*** than any of the other methods. Marginal skill exists for second-month outlooks but they are no better than climatology for later months. Precipitation forecast error now appears as the largest source of error in GLERL's forecasts of net basin supplies and lake levels.

LAKE SUPERIOR



PROBABILISTIC OUTLOOKS. Improvement of NWS climate outlooks will improve hydrological outlooks more than model improvements. Improved use of hydrological outlooks requires a redesign of how information is used. ***Probabilistic outlooks*** make fuller use of climate outlook information and obviate questions of choosing the "best" deterministic outlook. Since the groups of deterministic outlooks represent ***embedded classes*** of historical record segments, they form ***embedded probability intervals*** in the outlooks, containing successively higher information densities.

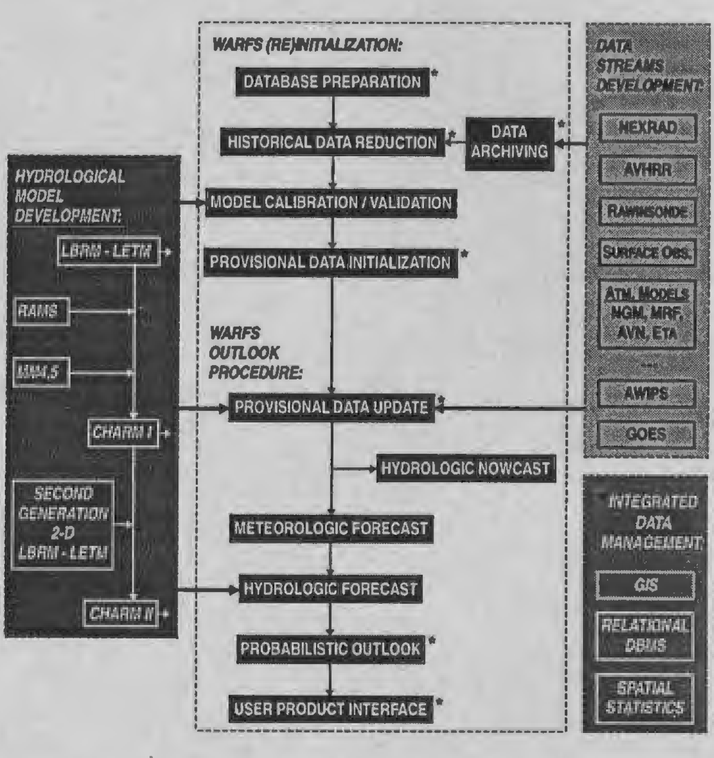
conditions, basin ***runoff***, lake ***heat storage*** conditions, lake surface ***water temperatures***, lake surface ***evaporation***, lake ***water supplies***, and ***water levels***. These ***water resource forecasts*** take advantage of the ***long-term memory*** of the Great Lakes system in the face of ***uncertain meteorology*** and can be made for any number of full months into the future. The package integrates modeling and near real-time data handling, is implemented in FORTRAN, and has been ported to MS-DOS and UNIX.



OUTLOOK PACKAGE. Inputs to GLERL's ***hydrology outlook package*** are daily meteorology for all available stations. Optional inputs are snow water equivalent, soil moisture, and surface water temperature. The point data are converted to areal averages for each watershed and lake surface by ***Thiessen weighting over digital maps*** of the areas. The areal averages are then utilized by GLERL's ***runoff model*** (applied to all 121 Great Lakes watersheds) and their ***lake thermodynamics model*** (applied to each lake) to estimate basin moisture and lake heat as initial conditions to a forecast. Sections of the historical record are then selected, for input to the models as possible future scenarios, which best match NWS probabilistic 30-day and 90-day ***climate outlooks***. These historical meteorologic sequences are grouped by how well they match the NWS outlooks and are used with the hydrology models to compute corresponding lake supply ***scenario groups***. Lake supply scenario groups are used with GLERL's ***lake regulation & balance model*** to determine lake level scenario groups. Deterministic or probabilistic outlooks then may be made from these scenario groups for each hydrological variable of interest. New provisional data are incorporated as they become available; new historical data also are used to update models and databases as they become available.

CURRENT RESEARCH. GLERL will consider the motif and the look and feel of the product interface, accounting for user wants and compatibility issues with NWS and others. ***We will build a user interface and an output product design into the existing forecast package.*** We will consider additional forecast products, appropriate hydrological variables, and the usefulness and form of the outlooks.

The National Weather Service Climate Analysis Center is switching from published *monthly & seasonal weather outlooks* to an electronic publication of *climate outlooks*. While still a probabilistic meteorological outlook, it offers longer lead times of 2 weeks to one year, alternate probabilistic interpretations, and new forecast techniques. ***GLERL will redefine its own probabilistic outlooks to make use of the new NWS climate outlooks.***



FUTURE RESEARCH:* WARFS.** GLERL is cooperating with NWS in building a Water Resource Forecasting System (WARFS) on the Great Lakes. Starting in FY1995 with NWS seed funds, it continues through FY2000 and consists of parallel efforts in ***process model development, ***data stream incorporation***, and ***integrated data management***. Our strategy for WARFS starts with GLERL's ***present*** water resource forecasting system, utilizing our ***current lumped-parameter models***, and adds to it our ***forthcoming distributed-parameter models***. Our existing lumped-parameter models will be integrated with atmospheric models to build a distributed-parameter Coupled Hydrologic Atmospheric Research Model (CHARM I). As our new distributed-parameter models for the atmosphere, lake thermodynamics, and land surface progress, they will be integrated into a second version (CHARM II). All will be available for implementation into WARFS. Thus, we will continue to serve a variety of present users, whose needs are satisfied with basin-wide outlooks based on GLERL's lumped-parameter models, while also servicing some of these and others with WARFS outlooks based on GLERL's developing distributed-parameter process models.